Reprinted from AGRONOMY JOURNAL
Vol. 68, January-February 1976, p. 49-55

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ABSTRACT

This study was conducted, under several climatic and soil conditions, to determine the effect of N level on sugarbeet yield and quality and to further develop and refine both soil and tissue test methods for predicting N fertilizer needs for efficient refined sucrose production. Previous studies indicate that N fertilizer needs for maximum sucrose production may be predicted by considering yield potential and all N sources.

Sugarbeets (*Beta vulgaris* L.) were grown under field conditions at N fertilizer levels varying from 0 to 448 kg N/ha on six sites throughout southern Idaho to determine root yield, sucrose percentages, sucrose yield, impurity index, and plant N uptake in relation to the residual NO_3-N, mineralizable N, fertilizer N, and petiole NO_3-N. These experiments demonstrated that the N fertilizer needs of sugarbeets can be determined by relating the root yield potential to the measured residual NO_3-N plus a measured or estimated mineralizable N level for an area. Optimum N level from all available soil and fertilizer sources has been found to vary between 5 to 6 kg/metric ton of beet roots produced. Using data from the current experiment and a previous study, N fertilizer could be predicted within 56 kg N/ha of that needed for maximum sucrose yield in 83% of the sites using measured NO_3-N and mineralizable N levels, 67% using measured NO_3-N and average mineralizable N levels, and only 12.5% using recommendations by fieldmen. Linear correlations were found between the total available N, total plant N uptake, other plant N variables, and root quality factors, like percentage sucrose and impurity index. These relationships confirm previous findings and will be useful for predicting root quality, optimum harvest date, and for verifying recommended fertilization practices. The use of the proposed soil and tissue test will improve root quality and sucrose production, as well as production efficiency, that will economically benefit the consumer, producer, and manufacturer.

Additional index words: N test, Petiole analysis, N uptake.

NITROGEN has the greatest influence of all the mineral elements on root quality and sucrose production of sugarbeets (*Beta vulgaris* L.). Sugarbeets grown with inadequate N generally have a high sucrose percentage and low impurities, but root and sucrose production are limited. Too much N increases root impurities while reducing sucrose percentage and, consequently, limits refined sucrose production (7). Optimum amounts of soil and fertilizer N are desirable for adequate top and root growth, while maintaining sufficiently high sucrose percentage and purity for profitable sucrose extraction and yield.

Soils vary widely in their ability to supply N for plant growth. This N-supplying potential varies with soil type, past fertilization and cropping history, as well as rainfall received and the irrigation water applied that affects the extent of N loss by leaching from soils (6, 13).

Most N fertilizer recommendations are based on past fertilization and cropping histories. Although some of these recommendations are reliable, many have been found to be excessive in southern Idaho (6). There is need for using both soil and tissue testing procedures for accurate fertilizer recommendations for maximum sucrose production and profits.

Methods have been developed for predicting N fertilizer needs for sugarbeets based on the amount of NO_3-N in the root zone (8, 11). However, mineralizable N has been found to be a major supplier of N for plant growth and to vary widely from one area to another (6, 13). For a N fertilizer prediction procedure based on a soil test to be applicable over a wide area with many soil types and management conditions, an estimate or measurement of mineralizable N is also needed. Recently, methods have been proposed (3) for more accurate recommendations that consider both the mineralizable N and NO_3-N. The objective of these experiments, under several climatic and soil conditions, was to further develop and refine these methods for predicting N fertilizer needs for maximum refined sucrose production.

THEORY AND BASIC RELATIONS

Previous studies have shown that for maximum sucrose yields, the N requirement is 5.5 ± 0.5 kg/metric ton of beet roots (3, 6). The upper limit of 6 kg N/metric ton of fresh beet roots was used in this study because farm managers generally apply more irrigation water than needed for maximum production, causing N loss below the root zone. At this rate, the potential yield, Y (metric ton/ha), for a sugarbeet field, if limited by N, will be:

$$Y = N_T/6, \quad N_T/6 \leqslant Y_E \tag{1a}$$

$$\text{or } Y/Y_E = N_T/6Y_E, \quad N_T \leqslant 6Y_E \tag{1b}$$

Where Y_E is the expected maximum yield under a given management level and climatic zone when N is not limiting (obtained from individual farm records), N_T (kg/ha) is the total net N available to the crop, determined as follows:

$$N_T = E_f N_f + \alpha_n N_n + \alpha_m N_m + N_r \tag{2}$$

where E_f = efficiency of applied N fertilizer (N_f),

$$\alpha_n = \frac{\text{crop extractable } NO_3\text{-N}}{NO_3\text{-N in the soil depth sampled}}$$

N_n = soil NO_3-N in the soil depth sampled

$$\alpha_m = \frac{\text{crop extractable mineralizable N}}{\text{field mineralizable N in soil depth sampled}} \times \frac{\text{field Min. N}}{\text{lab. Min. N}}$$

N_m = mineralizable N in the soil depth sampled, as determined by the laboratory mineralization tests

N_r = N immobilized or added by residue incorporated, $N_r = (n - n_o)R$, where n = N content of the residue when incorporated, n_o = expected N content in the residue at the end of the season, and R = residue added.

Detailed studies have indicated that when a Portneuf silt loam soil in southcentral Idaho near Twin Falls was sampled to the cemented zone, $E_f = 0.65$, $\alpha_n = 1.2$, and $\alpha_m = 0.95$ (3). These values were used throughout this study.

[1] Contribution from the Western Region, ARS-USDA; Univ. of Idaho College of Agriculture Research and Extension Center cooperating. Received 25 Apr. 1975.

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Table 1. Classification, previous crop, and soil properties of experimental sites used in the N study in southern Idaho.

Site no.	Approximate elevation	Initial N application	Soil classification: Designation	Subgroup and Family	Root zone*	Previous crop	Surface soil properties (0-15 cm): pH	OM	N
	m				cm			— % —	
				Southwestern					
20	730	Spring	Bahem vfsl	Xerollic Calciorthid‡	90	Potatoes	8.0	0.7	0.05
21	730	Spring	Power sil	Xerollic Haplargid §	60	Beans	7.7	1.5	0.10
				South Central					
110	1,220	Fall	Portneuf sil	Xerollic Calciorthid¶	55	Peas	7.7	1.4	0.09
111	1,190	Fall	Portneuf sil	Xerollic Calciorthid¶	45	Barley†	7.7	1.4	0.10
				Southeastern					
220	1,370	Spring	Portneuf sil	Xerollic Calciorthid¶	50	Potatoes	7.8	1.3	0.08
222	1,460	Spring	Pancheri sil	Xerollic Calciorthid‖	38	Beets	8.0	1.5	0.10

* Soil depth to hardpan or 150 cm. † Straw burned. ‡ Coarse-silty, mixed, mesic. § Fine-silty, mixed, mesic.
¶ Coarse-loamy, mixed, mesic. ‖ Coarse-silty, mixed, frigid.

The change in the N content of the residue during the growing season, $(n - n_o)$, combined with the efficiency of fertilizer N to compensate for this change, $(n - n_o)/E_f$, was reported as -7.5 kg N/metric ton of straw (R_s) in southern Idaho (12). If E_f is also assumed to be 0.65 when N fertilizer is added to compensate for the incorporated straw and $(\alpha_n N_n + \alpha_m N_m - 5 R_s) \leqslant 6Y_E$, the N fertilizer needed to make up the deficit for maximum sucrose yields, $6(Y_E - Y)$, will be:

$$N_f = \frac{6Y_E - (\alpha_n N_n + \alpha_m N_m - 5\ R_s)}{E_f} \qquad [3]$$

where N_f is the N fertilizer/ha needed, E_f is the expected N fertilizer efficiency (expressed as a fraction), and R_s is straw in metric tons/ha. After harvest, the yield response to N can be evaluated by substituting Y_{max} for Y_E in equation [1b].

MATERIALS AND METHODS

Six experiments were established throughout southern Idaho during the late fall of 1971 and early spring of 1972 (Table 1). The experimental sites, each with two replications, were located midway between the upper and lower ends of irrigated sugarbeet fields. The plots were fertilized with $Ca(NO_3)_2$ at rates of 0, 112, and 224 kg N/ha at two sites in the fall (fall plots), and at four other sites in the spring (spring plots). Fall plots were split by adding 0, 112, and 224 kg N/ha as NH_4NO_3 in late spring of 1972, while spring plots were split with 0, 56, and 112 kg N/ha. The irrigation variable on Site No. 111 received 0, 112, and 224 kg N/ha of spring-applied N only. The dimensions of the split plots were 6.1 by 10 m. Phosphorus was applied at a blanket rate of 50 kg P/ha at each location. Other nutrients, except N, were considered adequate for sugarbeet growth. All cultural operations were uniform for each site, and fertilizer was broadcast and disked into the surface 8 to 10 cm after application.

Each fall and spring plot was sampled to a 150-cm depth or to the hardpan in the late spring before planting and again in the fall of 1972. Twenty-four cores per treatment were composited by 15-cm depth increments to the 60-cm depth and by 30-cm depth increments below that depth. In addition, one 5-cm diameter auger sample was taken for each fertilizer treatment from the 45- to 150-cm depth. The soil samples were air dried, ground, and stored until analyzed. The potentially available soil N was determined as previously described (3, 6).

Part of the soil samples taken in the spring following the initial fertilizer application were inadvertently contaminated with ammonium during drying. Essentially no difference was found in the mineralization capacity between the uncontaminated samples taken in the spring and those taken in the fall. For this reason, total available N for sugarbeet growth was determined by combining the initial NO_3-N level found in the spring sampling with the mineralization capacity of the fall samples.

An irrigation variable on three rates of applied N was added to Site No. 111 only. Approximately 45 cm of irrigation water was applied in mid-July and water was applied to every furrow instead of alternate furrows during the remainder of the season. Irrigations of all other experiments, including the main part of Site No. 111, were applied to alternate furrows and were the same as those applied by the farm manager.

Twenty-four of the youngest, fully mature petioles were randomly sampled from each plot several times during the season. The petioles were cut into 0.5 cm sections, dried at 65C, ground to pass through a 40-mesh sieve, subsampled, and analyzed for NO_3-N using a nitrate specific ion electrode (10).

The beet tops, crowns, and roots from six uniform 3-m sections of row were harvested from each treatment at the end of the season to determine root yield, sucrose percentage, sucrose yield, impurity index, and total N uptake. Impurity index (2) and sucrose content were determined on two samples (14 kg each) of randomly selected roots from each plot by a sugar company, using their standard procedures. The beet pulp (collected during sucrose analysis), tops, and crowns were dried at 65C and their dry matter was determined. The dried samples were ground to pass a 40-mesh sieve, and total N in the samples was determined by the semimicro-Kjeldahl procedure modified to include nitrate (1). Nitrogen uptake was determined by assuming that the percentage N was the same in the fibrous and storage roots, and that the fibrous roots constituted 25% of the total harvested root weight (9).

The field numbers, location, soil classifications, previous crop, and surface soil properties of the six experimental sites are given in Table 1. Soil pH was determined using a glass electrode measurement in a soil-water saturated paste, percentage organic matter (OM) by a modified method of Walkley and Black (15), and percent total soil N by the Kjeldahl procedure modified to include nitrate.

RESULTS AND DISCUSSION

Considerable difficulty was encountered in relating the change in the preplant soil NO_3-N test to the amount of fertilizer N applied either in the fall or early spring. This was believed to be due partially to soil sampling problems caused by the movement of the fall-applied N into the hardpan and the uneven distribution with depth of the early spring-applied N. For this reason, the average $\alpha_m N_m$ and $\alpha_n N_n$ levels from the entire untreated area, plus 65% of the added fertilizer N, were assumed to represent total available N (N_T). In addition, data from similar fall and spring treatments were combined, since there were no significant differences between times of N application and plant response (low winter rainfall).

Results from the current and previous studies in southern Idaho, and other sugarbeet producing areas (3, 4, 6, 8, 11), have shown that sugarbeet root yield is increased by adding N fertilizer when N is limiting, and sometimes the yield may be decreased when excessive N is used, which was probably caused by the increased top growth (Fig. 1). These results also clearly show that the percentage sucrose decreases linearly with N_T. Sucrose yield followed a production pattern similar to root yield with maximum sucrose yield and profits at a N_T value slightly less than that required for maximum root yield.

The results obtained in this study show that the N_T needed for maximum root and sucrose yields can be predicted over a wide range in climatic conditions with corresponding large differences in yield potentials. Growing degree days [GDD = (max. temp. $\leqslant$ 25C + min. temp. $\geqslant$ 4.44)/2 − 4.44C][3] ranged from 2,040 to 2,450C-days (accumulated from March 1 to Oct. 24) in this study and maximum sugarbeet root yields were linearly related to GDD in 1972 ($Y_{max} = -83.3 + 0.063$ GDD, $r = 0.99$). These data indicate that in southern Idaho where solar radiation levels are similar, temperature and length of growing season caused by elevation differences seem to govern the yield potential. Therefore, when assuming 6 kg/ha of N_T are required per metric ton of beet roots, and using the linear equation for obtaining maximum root yield in 1972, the data clearly indicate that root yield is limited when N_T is less than required for maximum yield, and root yield may decrease when

[3] D. O. Everson. 1975. Growing degree day system for Idaho. Mimeographed. Univ. of Idaho, Moscow.

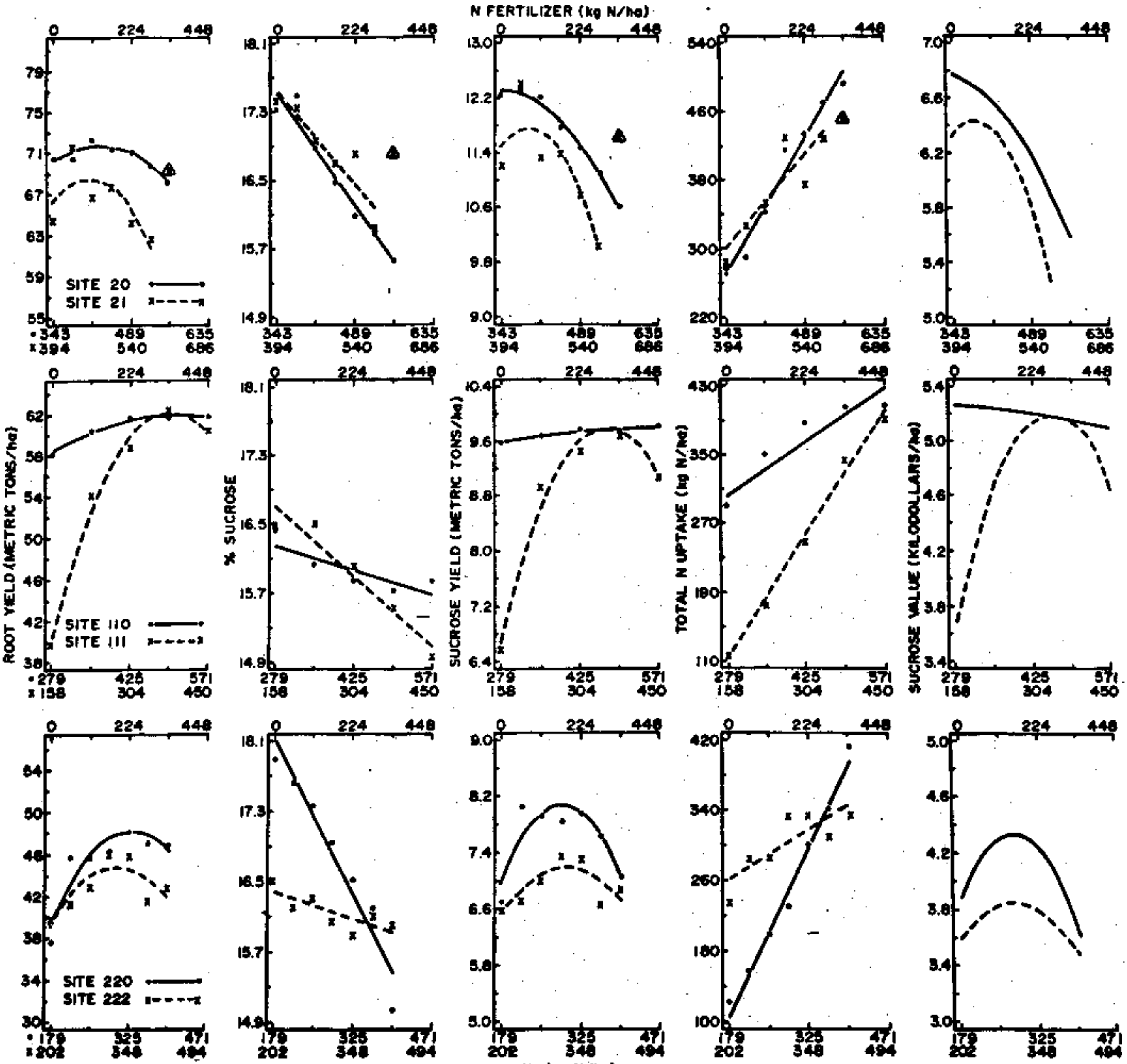

Fig. 1. Effect of N level on root yield, percentage sucrose, sucrose yield, total N uptake, and dollar value of sugarbeets in southern Idaho. (Dollar value of crop was based on sucrose yield from the regression line at \$0.55/kg of sucrose minus the fertilizer cost at \$0.66/kg of N. Δ excluded from data analysis because of stand variation).

Table 2. The effect of N fertilizer level and location on N uptake (N_{up}) and total available N (N_T)/metric ton of beet roots.

Treatment	Site 20		Site 21		Site 110		Site 111		Site 220		Site 222	
	N_{up}	N_T	N_{up}	N_T	N_{up}	N_T	N_{up}	N_T	N_{up}	N_T	N_{up}	N_T
kg N/ha	kg N/metric ton*											
0	3.92	4.86	4.39	6.11	5.00	4.75	2.95	3.96	3.30	4.79	5.90	5.06
56	4.10†	5.38†	4.57†	6.02†	–	–	–	–	3.46	4.73	6.99	5.79
112	4.74	5.74	5.29	7.01	5.86	5.79	3.25	4.28	4.32	5.54	6.66	6.40
168	5.83	6.33	6.32	7.40	–	–	–	–	4.95†	6.23†	7.30†	6.78†
224	6.12	6.85	5.86	8.40	6.18†	6.77†	4.42	5.17	6.30	6.79	7.30	7.57
280	6.77	7.54	6.84	9.20	–	–	–	–	7.21	7.66	7.46	9.27
336	7.22	8.22	6.53	8.83	6.61	8.04	5.56†	6.06†	8.76	8.45	7.83	9.82
448	–	–	–	–	6.61	9.15	6.48	7.43	–	–	–	–

* Average at maximum sucrose yield: $N_{up} = 5.44$, $N_T = 6.21$. † Maximum sucrose yield.

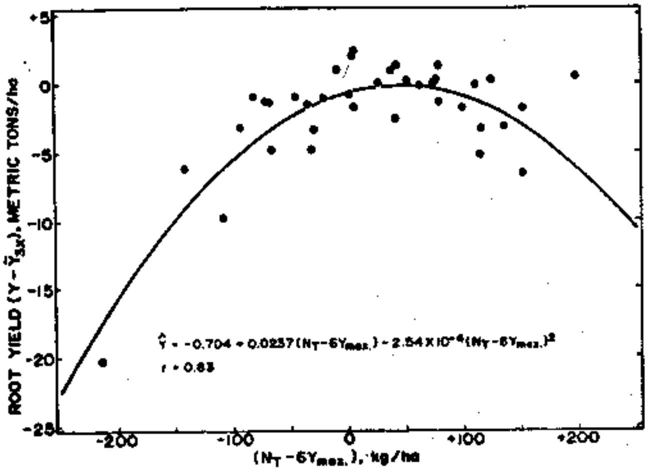

Fig. 2. Effect of variation from the optimum N level on root production on the 1972 experimental sites (Y_{max} = potential maximum root yield determined from growing degree days, Y = root yield, and $\bar{Y}_{3x}$ = average of three highest root yields).

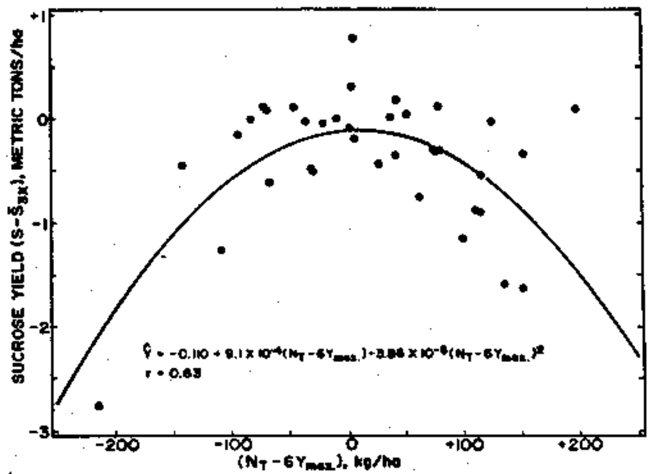

Fig. 3. Effect of variation from the optimum N level on sucrose production on the 1972 experimental sites (Y_{max} = potential maximum root yield determined from growing degree days, S = sucrose yield, and $\bar{S}_{3x}$ = average of three highest sucrose yields).

> 100 kg of N_T than required was available for maximum yields (Fig. 2).

Because of the linear decrease in sucrose percentage with increasing amounts of N_T, near maximum sucrose yields can be obtained when N_T is about 35 kg less than that required for maximum root yields (Fig. 3). Thus, if the grower is paid for gross sucrose production (root yield × % sucrose), he will obtain his greatest net return by applying slightly less than that amount of N fertilizer required for maximum root yield. But he will rarely obtain this return if excess N fertilizer is applied because of increased fertilizer cost and decreased sucrose yield (Fig. 1). The fertilizer application cost and other cultural operations will remain essentially constant.

The total N uptake (N_{up}) by the sugarbeet crop was linearly related to N_T at each of the six sites (Fig. 1) with the amount of N_{up} and N_T/metric ton of fresh beet roots varying with site and treatment (Table 2). Less N/metric ton was taken up under deficient N conditions and more N with excess available N. The total plant N_{up} averaged 5.4 kg and N_T averaged 6.2 kg/metric ton of fresh roots at maximum sucrose yield. These values were approximately the same as those reported previously (3, 6).

If the root yield potential for any sugarbeet field is known from previous production records or can be estimated from average maximum yield-growing degree days relationships as previously given for 1972, then the amount of N fertilizer necessary for maximum yields can be predicted using equation [3] as shown in Table 3, for a previous study conducted in 1971 (6) and the 1972 sites. If the estimated yield potential is too high for the level of farm management involved, or the root yield is limited due to insect damage, disease, poor stands, other nutrient deficiencies, or adverse climatic factors; then the N fertilizer recommended and applied will be greater than necessary and may reduce sucrose production. Actually, as shown in Fig. 2 and 3, maximum sucrose production is obtained if N_T is slightly less than that required for maximum root yields.

Although knowing the mineralization capacity of the soil on each field before making N fertilizer recommendations would be desirable, this may not be necessary if average data are available for the soil and climatic conditions of an area. The most accurate predictions of required N fertilizer can be made with measured mineralization data for each site. But (as shown in Fig. 4) using an average mineralization value for a large area (168 kg N/ha in southern Idaho) still results in a substantial improvement in predicting the N fertilizer required for maximum sucrose yield, as compared with fertilizer recommendations made by commercial distributors and sugar company fieldmen based on past fertilization and cropping histories. The

Table 3. Available N, N fertilizer recommendations, and N fertilizer level at maximum sucrose yield on the 1971 and 1972 experimental sites.

Exp. site no.	N recommendations based on			Maximum sucrose yield at	Exp. site no.	N recommendations based on			Maximum sucrose yield at
	N_T	$\alpha_n N_n$*	Fieldmen†			N_T	$\alpha_n N_n$*	Fieldmen†	
	kg N/ha					kg N/ha			
1†	0¶	7¶	101	0	156†	0¶	0¶	224	0
2†	0	0	168	0	157†	0	0	168	84
4†	0	0	224	0	110§	145	111	–	168
6†	129	122	202	0	111§	332	285	–	336
7†	230	172	168	168	201†	157	69	134	134
8†	96	81	258	129	202†	31	0	134	67
20§	142	67	–	56	204†	52	4	146	75
21§	56	76	–	56	205†	81	54	202	101
101†	265	224	179	179	206†	60	0	134	67
103†	35	105	157	0	207†	0	0	112	0
104†	58	59	196	97	208†	0	35	146	75
105†	0	0	168	0	210†	0	0	146	0
106†	86	136	112	56	211†	31	75	134	0
151†	0	0	168	0	220§	169	84	–	56
152†	0	0	179	0	222§	114	80	–	168
Avg. of all sites						76	61	166	69

* $\alpha_n N_n$ + average $\alpha_m N_m$ of 168 kg N/ha (150 lbs N/A). † Recommended N fertilizer rate by fertilizer and sugarbeet company fieldmen, based on past fertilization and cropping histories. † 1971 (6). § 1972. ¶ Calculated N fertilizer need for maximum yield if 6 kg N/metric ton of beet roots is required.

Table 4. Correlation between soil and Plant N variables, and quality of beet roots.

Exp. site no.	$\hat{Y}$												
	$N_T(x)$			$N_{up}(x)$		$N_T(x)$		$N_{up}(x)$		Int. average (x)*		Days to 1,000 ppm (x)†	
	N_{up}	Int. average*	Days to 1,000 ppm†		Int. average*	% Sucrose	Impurity index‡	% Sucrose	Impurity index‡	% Sucrose	Impurity index‡	% Sucrose	Impurity index‡
	r												
20	0.98	0.92	0.90	0.92	0.93	–0.98	0.91	–0.99	0.96	–0.86	0.91	–0.88	0.88
21	0.88	0.95	0.87	0.78	0.93	–0.93	0.79	–0.88	0.67	–0.97	0.75	–0.97	0.62
110	0.93	0.99	0.97	0.85	0.96	–0.84	0.82	–0.98	0.66	–0.88	0.80	–0.74	0.78
111	0.99	0.98	0.98	0.98	0.98	–0.97	0.99	–0.97	0.99	–0.99	0.98	–0.99	0.98
220	0.99	0.99	0.96	0.98	0.97	–0.97	0.96	–0.99	0.98	–0.93	0.98	–0.97	0.98
222	0.82	0.93	0.88	0.81	0.89	–0.79	0.78	–0.97	0.95	–0.87	0.86	–0.76	0.85
Average	0.93	0.96	0.93	0.89	0.94	–0.91	0.88	–0.96	0.87	–0.92	0.88	–0.89	0.85

* $\bar{N} = -\frac{N_O}{C}\,\frac{e^{-Ct_2} - e^{-Ct_1}}{t_2 - t_1}$, where $\bar{N}$ is the integrated average petiole NO_3-N, N_O is the NO_3-N concentration at the first sampling date, C is a constant for any given treatment or beet field, $t_1 = N_O$, t_2 = 9/1/72 (4).

† $t' = ln\,(N_O/1{,}000) \times (1/C)$, where t' is the number of days from N_O to 1,000 ppm petiole NO_3-N (4).

‡ Impurity Index = $\frac{10\ (\text{Amino N}) + 3.5\ (\text{Na}) + 2.5\ (\text{K})}{\text{Sucrose \%}}$.

data shown in Fig. 4 include the results from this study in addition to those from a similar previous study conducted in 1971 (6). Predictions were within 56 kg N/ha of that needed for maximum sucrose yield in 83% of the sites using N_T, 67% using $\alpha_n N_n$ + the average $\alpha_m N_m$, and only 12.5% using recommendations by fieldmen. Using an average mineralization value was nearly as accurate as using the measured value for most sites. The largest deviation in predicting N needs by the average value occurred where there were large variations from the average mineralization capacity of the soil involved.

The frequency distribution of differences in increased returns from sucrose production using N fertilizer recommendations based on N_T as compared to those made by fieldmen for the 1971 study (6) is given in Fig. 5. The average gain by the use of N_T would be \$280/ha (\$113/acre) with an average decrease of N fertilizer of 110 kg/ha (98 lbs/acre). If these 24 experimental sites are representative of the sugarbeet fields, and if N fertilization practices on sugarbeets have not changed substantially since 1972, then the overall annual gain by use of N_T as proposed would be near \$19 million in southern Idaho alone (69,230 ha). The cost of soil sampling and testing would depend upon field size and soil variability but in most cases would be minimal in comparison with the benefits. There would also be a further gain in the return to the grower by using N_T since he is normally paid for the refined sucrose produced. Excess N, that is normally applied without a soil test, reduces the extractable sucrose because of high root impurities. Potential increase in returns to the grower is so large that an investment in a soil test for NO_3-N and mineralizable N, utilizing a representative soil sample from the field in question, would usually return manyfold profits to the growers in southern Idaho.

Further evidence that the procedures proposed in this paper for predicting N fertilizer needs are supported by the high degree of linear correlation between N_T and total plant N_{up} on most sites (Table 4). Similarly, the high linear correlation between N_T or N_{up} and the integrated average petiole NO_3-N, or the days for petiole NO_3-N to decrease to 1,000 ppm

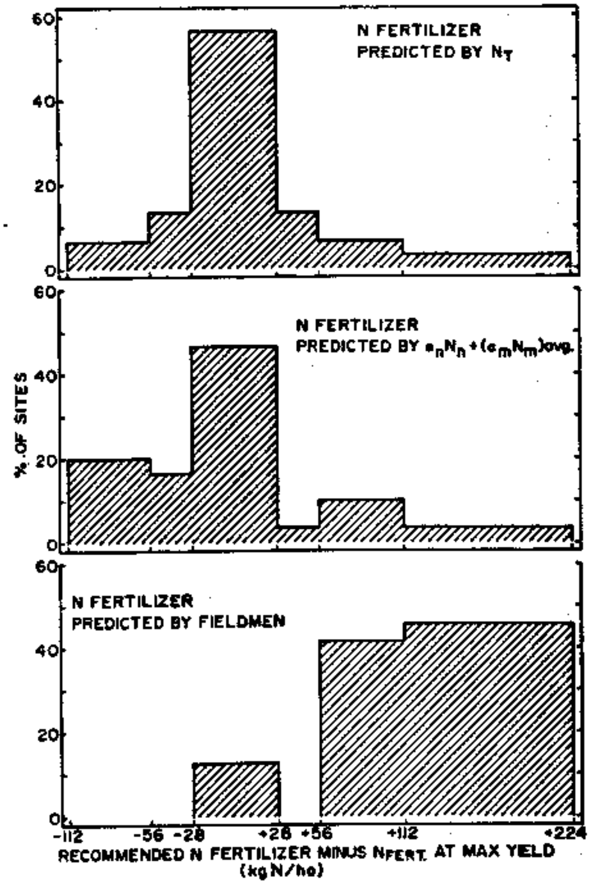

Fig. 4. Frequency distribution of N fertilizer recommendations when compared to that required for maximum sucrose yield on 24 sites in 1971 and 6 sites in 1972.

are also apparent. Plant tissue analyses are used to monitor the current status of N available to the plant and the scheduling of harvesting operations. There is also a high degree of correlation on most sites between these N variables and quality factors of sugarbeets, like percentage sucrose and impurity index. These data further support the conclusions of other studies in southern Idaho which showed that both yield and quality of sugarbeets could be predicted using these soils and plant variables (3, 4, 6).

Previous publications indicated that excessive irrigation water applied early in the season significantly influences the yield when N was limited (4); but excess irrigation water applied late in the season, when the NO_3-N concentration in the soil was lowest, had little effect on sucrose percentage (5). In this study, excess irrigation water was applied in midseason, but it also had very little effect on yield or plant N variables. Apparently, on this site, the NO_3-N concentration in the soil was sufficiently depleted on all treatments so that very little NO_3-N was leached below the root zone where it could not be recovered by the roots. This is further verified by previous unpublished data which showed that the concentration of NO_3-N in the soil solution at the 1-m depth was < 0.03 mg/ml by August 1. The majority of the potentially available N for the balance of the season was probably still present in mineralization form, therefore unavailable for leaching.

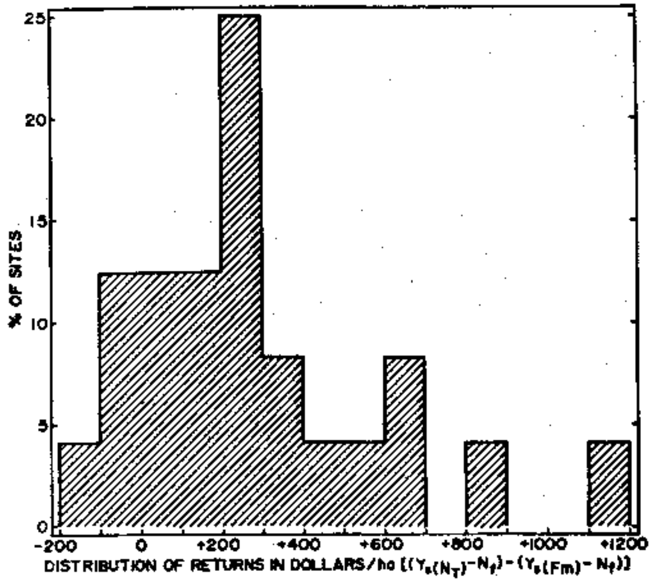

Fig. 5. Frequency distribution of the difference in increased returns from sucrose production when using N fertilizer recommendations based on a soil test (N_T) as compared to those made by fieldmen (F_m) on 24 sites in 1971 (Y_s = sucrose yield at \$0.55/kg, N_f = N fertilizer at \$0.66/kg).

The rate of decrease in percentage sucrose (S) depended upon the rate of increase in total plant N_{up} with fertilizer additions $[\hat{Y}(\Delta S/\Delta N_T) = 0.0018 - 0.0015 (\Delta N_{up}/\Delta N_f),\ r = 0.94]$ (Fig. 1). This supports previous findings (4) that sucrose concentration may be influenced more by the maximum rate of N_{up} early in the season than the N available later in the season. This is further suggested by the data reported by Hills and Ulrich (7), and Storer et al. (14), which showed that differences in sucrose percentage are established at an early date. Other experimental data obtained in Idaho also support this hypothesis. For example, effect of N leaching was small with excessive irrigation water during midseason in this study and late in the season in an earlier study (5).

The results obtained in this study and those reported previously (3, 6) clearly indicated that a soil test to determine the residual NO_3-N and mineralizable N is an effective method for predicting the amount of N fertilizer required for maximum sucrose production. In most sugarbeet growing areas, either state sponsored or commercial soil test laboratories are available for making these determinations. Obviously, an important factor in obtaining a reliable soil test is first obtaining a representative soil sample within the root zone from the entire sugarbeet field. The NO_3-N level in a soil can be rapidly and accurately determined in a soil test laboratory. Since the mineralizable N does not change significantly from one year to the next; once it has been determined for a field, this value or an average value for the area would probably be adequate except where the cropping systems or fertilizer practices are radically changed (3). The use of optimum N levels, based on both soil and tissue tests, will improve root quality and sucrose production, as well as production efficiency, that will economically benefit the consumer, producer, and manufacturer.

ACKNOWLEDGMENT

The authors express appreciation to Mr. Darrell L. Gallup, State Soil Scientist, Soil Conservation Service, and his staff for assistance in the soil classification, and to S. M. Bosma, S. E. Crothers, and B. J. Ruffing for their invaluable assistance in the field and laboratory work.

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